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Deficient Contractor Business Systems: Applying the Value at Risk (VAR) Model to Earned Value Management Systems

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LIST OF ACRONYMS AND ABBREVIATIONS

ACO	Administrative Contracting Officer
ACWP	Actual Cost Work Performed
BAC	Budget at Completion
BCWP	Budgeted Cost Work Performed
CAPE	Cost Assessment Program Evaluation
CAR	Corrective Action Request
CV	Cost Variance
DAU	Defense Acquisition University
DCMA	Defense Contract Management Agency
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
EAC	Estimate at Completion
EL	Expected Loss
EVM	Earned Value Management
EVMS	Earned Value Management Systems
GAO	Government Accountability Office
GL	Guidelines
LOE	Level of Effort
MDAP	Major Defense Acquisition Program
MR	Management Reserve
PMB	Performance Measurement Baseline
PMS	Project Master Schedule
SV	Schedule Variance
UL	Unexpected Loss
VaR	Value at Risk
VV&A	Verified, Validated, and Accredited
WBS	Work Breakdown Structure

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I. INTRODUCTION

A. BACKGROUND

1. Deficient Contractor Business Systems

In the world of Department of Defense (DoD) acquisition and contracting, managing costs is critical to sustaining program success and preventing misused resources in government contracts. According to the Commission on Wartime Contracting (2009b), "[c]ontractor business systems and internal controls are the first line of defense against waste, fraud, and abuse" (p. 1) and are essential to managing cost risk to the government. In 2009, the Commission on Wartime Contracting found multiple deficiencies in contractor business systems and internal controls. As a result, Section 893 of the National Defense Authorization Act (NDAA) for Fiscal Year 2011 mandated the Secretary of Defense to implement a program to improve the oversight of contractor business systems.

The Defense Federal Acquisition Regulation Supplement (DFARS) Clause 252.242–7005 identifies six contractor business systems: accounting, estimating, purchasing, earned value management (EVM), material management, and property management. In the event that any business system demonstrates a significant deficiency in which it is unable to produce reliable cost management data, demonstrating risk to the government, contractor payments of up to 5% can be withheld for each deficient system (DFARS, 2013). Although the DFARS business system rule identifies six systems, this paper focuses solely on the Earned Value Management System (EVMS).

The next section introduces the role of EVMS within the Defense Contract Management Agency (DCMA) and its definition of a significant deficiency.

2. Earned Value Management System

EVM is the DoD's primary tool for measuring acquisition program cost, schedule, and performance. EVM data are measured against the contract's performance measurement baseline to monitor progress and ensure the least cost risk to the government (Snider & Dillard, 2008). Mahoney and Rego (2011) described EVM as "a systematic approach to the integration and [measurement] of cost, schedule, and performance on projects, [which] provides an early warning system for potential threats and opportunities" (p. 67). Correspondingly, the EVMS validation done by DCMA serves as an assessment of EVM data to certify that processes are in accordance with the 32 EVMS guidelines as issued by the American National Standards Institute/Electronic Industries Association (ANSI/EIA) 748 (DCMA, 2011). Dibert and Velez (2006) stated that the guidelines provide a practical approach to effective project management.

Understanding EVMS compliance and deficiencies first requires a working knowledge of how the process is monitored, annotated, and corrected. The next section discusses the DCMA's EVMS role, EVMS surveillance procedures, and the consequences of non-compliance.

a. Defense Contract Management Agency (DCMA) EVMS Surveillance

The DCMA functions as the DoD Executive Agent and Compliance Authority for EVMS compliance (DCMA, 2012a). The DCMA conducts EVMS surveillance upon contract award for all contracts valued over $20 million, which contain the EVMS Federal Acquisition Regulation (FAR) or DFARS clause (DCMA, 2012a). EVMS surveillance ensures that contractor EVM data are in compliance with the 32 EVMS guidelines as issued by ANSI/EIA 748. However, the present research project focuses only on 13 EVMS guidelines that Senior DCMA EVM specialists have identified as high-risk guidelines that require annual evaluations as shown in Table 1.

Table 1. DCMA 13 High Risk EVMS Criteria (from Dibert & Velez, 2006)

EVMS Criteria	**13 "High Risk" Criteria**
EVMS Group # 1: Organization	
# 1	Define Authorized Work (WBS Elements)
# 3	Integrate the System
EVMS Group # 2: Planning, Scheduling, and Budgeting	
# 6	Schedule the Work
# 7	Identify Products, Milestones, and Indicators
# 8	Plan the Performance Measurement Baseline (PMB)
# 9	Establish Budgets for Work
# 10	Identify Work Packages
# 12	Identify and Control Level of Effort
EVMS Group # 4: Analysis	
# 23	Analyze Schedule and Cost Variances
# 26	Implement Managerial Actions
# 27	Develop Revised Estimates of Cost at Completion
EVMS Group #5: Revisions	
# 28	Incorporate Changes into Plans, Budgets, and Schedules
# 32	Document Changes to the PMB

b. Significant Deficiencies

The DCMA's annual surveillance of the 13 high risk EVMS guidelines is the process that can approve or disapprove a contractor's EVMS (DCMA, 2012a). Failure to meet ANSI/EIA 748's standards for any of the 13 guidelines results in a significant deficiency and disapproval of the EVM system. DFARS Clause 252.234–7002(a) defines a significant deficiency as a "shortcoming in the system that materially affects the ability of officials of the Department of Defense to rely upon information produced by the system that is needed for management purposes" (DFARS, 2013, Sec 252.242–7005).

Therefore, if a contractor's EVMS fails to meet one or more high risk guidelines (1, 3, 6, 7, 8, 9, 10, 12, 23, 26, 27, 28, and 32), the system is considered to have a significant deficiency and withholding of progress payments is required (DFARS, 2013). However, DCMA's Administrative Contracting Officer (ACO) have the discretion to determine the level of the Corrective Action Request (CAR) based on the severity of the deficiencies (CAR, 2013). Table 2 describes the different CAR levels and action required.

Table 2. CAR Levels (CAR, 2013)

CAR Level I	**Deficiencies are minor in nature and can be quickly corrected**
CAR Level II	**Deficiencies require time to correct and a corrective action plan by contractor is required**
CAR Level III	**Contractor failed to correct Level II deficiencies in a timely manner, warrants a "significant deficiency," and withhold of progress payments**
CAR Level IV	**Deficiencies are severe and pose a high risk to contract performance**

As of August 16, 2011, the new business systems rule authorizes DCMA ACOs to withhold a maximum of 5% of contractor progress payments on all DCMA Level III and above CARs until the significant deficiencies have been corrected (DFARS, 2013). Once the contractor makes progress towards implementing their corrective action plan, the ACOs have the discretion to reduce the withhold percentage.

Lockheed Martin is the first contractor from which the DCMA has withheld payments since implementing the new business rule (Fast, 2012). In October

2012, the DCMA withheld $46.5 million from Lockheed Martin for two F-35 contracts that were overrunning by approximately 70% in cost and delayed in schedule (Cappacio, 2012). As of April 2013, the withhold amount increased to $130 million as a result of failing to implement a corrective action plan for the deficiencies (Cappacio, 2013). The progress payments totaling $130 million equate to 5% of funds spent by Lockheed Martin for both contracts (Cappacio, 2013). The DCMA has no plans to release the funds until progress towards improving significant deficiencies are demonstrated and in compliance with the EVMS standard guidelines.

This problematic situation with Lockheed Martin cautions DCMA officials to ensure EVMS compliance and significant deficiencies are correctly measured in order to implement the business system payment withholding rule. As Naval Postgraduate School Senior Lecturer William Fast, stated, “[T]he financial impact and materiality of the deficiency is difficult to quantify–since it is the inaccurate and unreliable data produced by the business system–that is (in fact) the deficiency” (Fast, 2012, p.17). Therefore, exploring objective and quantitative ways to identify a significant deficiency and calculating government risk in dollars is the reason behind this study. The next section describes the motives for our research.

B. PURPOSE OF STUDY

The purpose of this research is to objectively and quantitatively portray EVMS risk in a way that supports a monetary withhold decision and can withstand objection (to include litigation) from the defense contractor. In this project, we hypothesize that using quantitative risk models such as Value at Risk (VaR) methods and simplification of that business model for use by contracting officers provides value to DCMA professionals in the implementation of the new business rule. The project seeks to provide the DCMA with a more defensible risk value model as the basis for withholding contractor payments. The next section describes the focus and priority of the research project.

C. RESEARCH OBJECTIVES

Three principal objectives define the project and set the priorities of the research.

1. Determine whether the 13 EVMS “high risk” guidelines can be grouped with respect to root causes (causality of risk).
    - Evaluate the rank or natural order to the potential severity of the deficiency posed by these guidelines.
    - Assess the degree of interdependence or causality across the 13 critical EVMS guidelines.
2. Evaluate which quantitative method(s) can be used to calculate risk value with respect to non-compliance with both critical and non-critical guidelines.
    - Evaluate which quantitative definition of “significant deficiency” is applicable.
3. Determine the relationship of risk value calculations and findings of EVMS non-compliance with (a) probability of error, (b) magnitude of errors, and (c) adverse impact of errors.
    - Develop a deterministic rule set that yields a consistent and repeatable finding of significant deficiency.

The next section suggests how relevant stakeholders can benefit from the research.

D. RESEARCH BENEFITS

Preventing and mitigating fraud, waste, and abuse of taxpayer dollars is the ultimate benefit of this project. In 2009, the Commission on Wartime Contracting found that the DCMA lacked an effective system that enforced EVMS compliance among contractors (DCMA, 2009b). With the recent federal business rule in effect, DCMA ACOs now have the withholding authority to motivate contractors to comply; however, the agency is under-resourced to implement the rule objectively (Fast, 2012). Therefore, a quantitative risk model that is simplified for use by DCMA contracting officers in the implementation of the recent business system rule can provide the following advantages:

- Objective and quantitative assessment of the 13 critical EVMS guidelines justifies appropriate withhold amounts if necessary, thus providing a litigation safety net for the DCMA.
- The DCMA has a simplified risk analysis tool, which helps alleviate the issue of being under-resourced to motivate contractors to comply with EVMS surveillance processes and criteria.
- A risk analysis model used in assessing compliance provides informative audit reports that help ACOs make effective contracting decisions well beyond the decision to withhold payments.
- Understanding root causes and any correlations between the critical criterion deficiencies can provide decision-makers with credible data to improve current EVMS processes and procedures.

E. SUMMARY

The introduction included three main topics of discussion. The first topic we addressed was deficient contractor business systems and the new business rule of withholding 5% of the contractor progress payment when a significant deficiency is present. The second topic focused on EVM business systems and the DCMA's role in monitoring a contractor's EVMS for compliance. The final topic discussed the purpose of our research and the benefits we can provide to the DCMA. The next chapter establishes a working knowledge by exploring EVMS criteria in detail.

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II. DCMA'S 13 "HIGH RISK" EVMS CRITERIA

A. PREFACE

This chapter provides a detailed description of the selected 13 high risk guidelines (1, 3, 6, 7, 8, 9, 10, 12, 23, 26, 27, 28, or 32) that the DCMA evaluates for significant deficiencies. Understanding the criteria in better detail assists in determining root causes of significant deficiencies, which then paves the way to developing a methodology that identifies the ranking of severity for each of the high risk non-compliant guidelines.

Each essential criterion represents logical "best practices" in both the Department of Defense and the private sector, which would benefit any project or program manager (Fleming & Koppelman, 2012). The 13 guidelines are grouped into five categories, which are (1) *Organization,* (2) *Planning, Scheduling, and Budgeting,* (3) *Analysis,* (4) *Accounting,* and (5) *Revisions*. The *Accounting* category is excluded from the 13 high risk guidelines because it is a separate business system under the surveillance responsibility of the Defense Contracts Audit Agency (DCAA). Therefore, the 13 criteria fall under only four of the five categories.

B. EVMS "HIGH RISK" CRITERIA

1. Group 1—Organization

The first category of *Organization* contains criteria 1 and 3, which clearly define the range of requirements prior to the project commencing (Fleming & Koppelman, 2012). Fleming and Koppelman (2012) defined the following criteria as such:

a. EVMS Criterion #1: "Define the authorized work elements for the program. A work breakdown structure (WBS), tailored for effective internal management control, is commonly used in this process (p. 3698)"

The first criterion suggests the use of a WBS to group segments of work in an organized manner by hierarchy. All deliverables must be documented and grouped under a major segment in the WBS, which ensures that project managers understand their scope of responsibilities in order to measure performance (Fleming & Koppelman, 2012).

A common issue that causes a significant deficiency in this criterion is a poor definition of the project's range of deliverables (i.e., it's WBS, product specifications), resulting in wasted resources in regards to time, schedule, and performance (Fleming & Koppelman, 2012).

b. EVMS Criterion #3: "Provide for the integration of the company's planning, scheduling, budgeting, work authorization, and cost accumulation processes with each other, and, as appropriate, the program WBS and the program organizational structure (p. 3720–3728)"

The third criterion requires the incorporation of organizational management in conjunction with the WBS to include identifying the functional teams responsible for each work package (Fleming & Koppelman, 2012). Additionally, the third criterion requires an information database process to be created for all functional teams within the project. Interestingly, large defense contractors typically fail at satisfying this criterion due to functional sections maintaining opposing project goals and processes (Fleming & Koppelman, 2012).

2. Group 2—Planning, Scheduling, and Budgeting

The second category of *Planning, Scheduling, and Budgeting* contains criteria 6, 7, 8, 9, 10, and 12, which requires a management control system that links the formal planning, scheduling, and budgeting of a project into a performance measurement baseline (PMB). This group of criteria establishes a project baseline that allows for a formal means of project discipline and assessment. Fleming and Koppelman (2012) define the following criteria as such:

a. EVMS Criterion #6: "Schedule the authorized work in a manner that describes the sequence of work and identifies the significant task interdependencies required to meet the requirements of the program (p. 3781–3788)"

The sixth criterion requires a project to establish a project master schedule (PMS) for all projects within the WBS (Fleming & Koppelman, 2012). The PMS must reflect key milestone dates organized in a manner to achieve optimal progress within the project. Due to multiple project changes, the most common compliance issue lies in adhering to the PMS and critical deadlines (Fleming & Koppelman, 2012).

b. EVMS Criterion #7: "Identify physical products, milestones, technical performance goals, or other indicators that will be used to measure progress (p. 3796)"

Similar to the sixth criterion, the seventh criterion must identify tangible products and deliverables based on the WBS in order to measure earned value (Fleming & Koppelman, 2012). This criterion requires contractors to describe what products will be developed or delivered by a certain milestone date. However, the major conflict with this criterion requires contractors to clearly identify the completed phase of the physical product or deliverable in accordance with the schedule (Fleming & Koppelman, 2012).

c. EVMS Criterion #8: "Establish and maintain a time-phased budget baseline at the control account level, against which program performance can be measured (p. 3803–3810)"

"Initial budgets established for performance are based on either internal management goals or the external customer-negotiated target cost, including estimates for authorized but unpriced work. Budget for far term efforts may be held in higher-level accounts until an appropriate time for allocation at the control-account level. On government contracts, if an over-target baseline is used for performance measurement reporting purposes; prior notification must be provided to the customer."

Criterion 8 requires a complete and formal PMB in order to measure all components of the project (Fleming & Koppelman, 2012). Budgets are developed and work is scheduled to be completed within the scope of the project. Fleming and Koppelman (2012) emphasized that the PMB is critical to establishing a framework in which the earned value of a project or program can be measured in accordance with time, schedule, and performance.

d. EVMS Criterion #9: "Establish budgets for authorized work with identification of significant cost elements (labor, material, etc.) as needed for internal management and for control of subcontractors (p. 3841)"

The ninth criterion is critical to ensuring the right budgets are in place for the project. All costs to include material, labor, subcontracts, and travel must be included in the budgeting phase (Fleming & Koppelman, 2012). Furthermore, Fleming and Koppelman stated that budgets must be assigned to respective project sections and any budget changes will only pertain to authorized work as defined in the WBS.

e. EVMS Criterion #10: "To the extent that it is practical to identify the authorized work in discrete work packages, establish budgets for this work in terms of dollars, hours, or other measurable units. Where the entire control account is not subdivided into work packages, identify the far-term effort in larger planning packages for budget and scheduling purposes (p. 3848–3855)"

The tenth criterion focuses on clearly defining the work packages within the WBS with a clear distinction for the near and long term (Fleming & Koppelman, 2012). Additionally, established budgets containing numerical measures (hours, dollars, etc.) must link to the actual work function to be performed (Fleming & Koppelman, 2012).

f. EVMS Criterion #12: "Identify and control level-of-effort (LOE) activity by time-phased budgets established for this purpose. Only that effort that is unmeasurable, or for which measurement is impractical, may be classified as LOE (p. 3870)"

The remaining criterion in the planning, scheduling, and budgeting group emphasizes the avoidance of level of effort (LOE) activities such as "the project manager and staff, a field support engineer, guard services" (Fleming & Koppelman, 2012, p. 70). These activities are measured by the passage of time rather than actual tangible deliverables and are unable to be measured in earned value. Thus, Fleming and Koppelman stated that LOE activities must be immediately identified, have strict budget controls, and be avoided to the maximum extent.

3. Group 4—Analysis

The fourth category of *Analysis* contains criteria 23, 26, and 27, and requires routine submission of EVM data such as cost and schedule variances to maintain effective project management (Dibert & Velez, 2006). Any variances from the PMB or PMS must be evaluated and a corrective course of action must be in place to minimize any negative impact to the project (Dibert & Velez, 2006). Fleming and Koppelman (2012) defined the following criteria as such:

a. EVMS Criterion #23: "Identify, at least monthly, the significant differences between both planned and actual schedule performance and planned and actual cost performance, and provide the reasons for the variances in the detail needed by program management (p. 4050)"

The 23rd criterion recommends that variances in schedule and cost be reported on a monthly basis. Once a variance threshold is exceeded, project managers must determine the cause for a change in the performance measurement baseline to include developing corrective actions immediately (Fleming & Koppelman, 2012). Furthermore, this criterion applies to outside suppliers or subcontractors of the current project. A main issue with this criterion is a lack of communication between the contractor and subcontractor in EVM reporting standards and managing variances.

b. EVMS Criterion #26: "Implement managerial actions taken as the result of earned value information (p. 4087)"

Fleming and Koppelman (2012) suggested a process that ensures corrective courses of action are implemented as a result of exceeding any variance threshold. Criterion 26 states that projects may have a set point at which cost is over or under and schedule is ahead or behind, at which management should implement corrective actions to lessen any negative impact to the project (Fleming & Koppelman, 2012).

c. EVMS Criterion #27: "Develop revised estimates of cost at completion based on performance to date, commitment values for material, and estimates for future conditions. Compare this information with the PMB to identify variances at completion important to company

management and any applicable customer-reporting requirements, including statements of funding requirements (p. 4095)"

The 27th criterion focuses on the project's estimate at completion (EAC), which should be continuously updated and compared against actual work completed and the initial budget baseline (Fleming & Koppelman, 2012). Fleming and Koppelman stated that authorized work must be budgeted, and often different project sections fail to accurately estimate the final project costs, thus distorting the estimate of costs at project completion. Most importantly, EACs should frequently be compared with the PMB in order to mitigate cost issues as soon as possible (Dibert & Velez, 2006).

4. Group 5—Revisions

The last category, *Revisions*, contains criteria 28 and 32, which require approved changes to the project in a timely manner to allow for integration (Fleming & Koppelman, 2012). Fleming and Koppelman (2012) defined the following criteria as such:

a. EVMS Criterion #28: "Incorporate authorized changes in a timely manner, recording the effects of such changes in budgets and schedules. In the directed effort prior to negotiation of change, base such revisions on the amount estimated and budgeted to the program organizations (p. 4134)"

Fleming and Koppelman (2012) stated that the 28th criterion solely focuses on integrating changes in a timely manner. Defining what is timely poses a major issue for this criterion due to the type of changes that would need to be merged into the project baseline (Fleming & Koppelman, 2012). Additionally, Fleming and Koppelman emphasized the importance of ensuring that all work changes are immediately documented and work value estimated into the PMB.

b. EVMS Criterion #32: "Document changes to the PMB (p. 4170)"

The final criterion 32 serves as an accounting measure to ensure all changes are documented in sequence against the approved PMB (Fleming & Koppelman, 2012). Project changes are inevitable; thus, a tracking system of changes is imperative.

Failure to document changes to the PMB defeats the purpose of EVMS and EVM data management (Dibert & Velez, 2006).

C. SUMMARY

This chapter described each of the 13 high risk EVMS guidelines in detail, which offers a better understanding of how to determine root causes and severity of EVMS significant deficiencies. The next chapter covers the extent of quantitative risk analysis used in DoD acquisition programs and proposed methodologies for this project.

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III. QUANTITATIVE RISK ANALYSIS IN DOD ACQUISITION PROGRAMS

A. PREFACE

The implementation of quantitative risk analysis in DoD acquisition programs is the first step in creating a framework and methodology of concepts, topics, issues, and data pertaining to our research topic. Key concepts that drive our progress towards achieving our research objectives consist of the following:

- Quantitative Risk Analysis
- Operational Value at Risk
- Pairwise Comparison

Exploring these three primary areas provides the link between the research questions, analysis, and application of the operational VaR model to EVMS.

B. QUANTITATIVE RISK ANALYSIS

The use of quantitative cost risk analysis tools can be valuable in measuring numerical risk to the government (Galway, 2004). However, quantitative risk analysis is rarely utilized in DoD acquisition programs because the methods are not easily comprehended by project managers or integrated into programs (Fast, 2012). In fact, Fast discovered that quantitative assessment is only mentioned once in the Risk Management Guide for DoD Acquisition. The current Guide (Under Secretary of Defense for Acquisition, Technology, and Logistics (USD [AT&L], 2006) focuses on the general risk management process to mitigate risks, demonstrating a more qualitative assessment of risk (Fast, 2012).

EVMS is used as a risk management tool for the overall program life cycle, but the DoD Risk Management Guide does not address a quantitative assessment of the EVMS itself. Galway (2004) practically linked project quantitative risk assessment to EVM by focusing on cost, schedule, and performance risks.

Fast (2012) recommended that the current DoD Risk Management Guide be revised to include more quantitative risk analysis methods. The DoD Risk Management

Guide (Under Secretary of Defense for Acquisition, Technology, and Logistics (USD [AT&L], 2006) identifies three components of risk: a future root cause, probability of root cause occurring, and the consequence of the root causes occurring. Fast (2012) suggested that:

> simply multiplying the probability of a risk event (expressed as a decimal) by a monetized severity of loss would yield a monetary risk number. Adding up all of those monetary risk numbers for all elements of an acquisition program would provide an informative, albeit somewhat simplified quantitative risk assessment. (p. 5)

Therefore, identifying the cost to correct and process a CAR level III deficiency would lead to obtaining a monetized severity of loss in dollars, which will be discussed in our later chapters. The probability of a significant EVMS deficiency occurring in a DoD acquisition project is multiplied by the monetized severity of loss of that deficiency. This calculation can then provide a quantitative risk value that could justify payment withholdings, which Chapter V discusses in further detail.

The following section focuses on the Operational VaR approach that can be applied in computing the VaR for significant deficiencies within a program's EVMS.

C. OPERATIONAL VALUE AT RISK

The VaR method originated in the 1960s when economist Harry Markowitz discovered the concept of measuring risk for bank portfolio assets (Damodaran, 2007). In the last few years, financial analysts and statisticians have brought forward various risk measurement techniques for investment traders due to an increase in trading activities and uncertainty in the financial market (Hendricks, 1996). In business, VaR is defined as measuring "the worst expected loss that an institution can suffer over a given time interval under normal market conditions at a given confidence level" (Butler, 1999, p. 5).

The VaR method can create value in the acquisition workforce by estimating the government's VaR as a result of contractor's performance. Thus, the VaR method is proposed as the quantitative risk model for use by government contracting officers when justifying the withholding of contractor payments for a significant deficiency in the contractor's EVMS (Fast, 2012).

Jorion (2007), a well-known author on how financial institutions and the insurance industry calculate financial risk using the VaR method describes *Operational Value at Risk* as “the risk of loss resulting from inadequate or failed processes, people, and systems or from external events” (p. 495).

Fast (2012) described operational risk as the cause of corporate scandals such as the Enron scandal in 2001 and the bankruptcy of Lehman Brothers in 2008. Both cases are an example of poor corporate accountability and transparency such as a compliance failure, which can be attributed to operational risk. Likewise, operational risk in government contracting can be associated with the risk of loss resulting from failed processes or systems such as the EVMS.

Operational risk is based on the frequency and severity of the expected and unexpected losses in which two types of loss distributions can occur. High frequency/low severity losses typically consist of small accounting errors due to daily transactions or lack of internal control (Fast, 2012). These are expected losses. Alternatively, low frequency/high severity losses are considered disastrous loss events that pose the highest risk to an organization and could result in bankruptcy (Fast, 2012). These are unexpected losses.

Jorion (2007) measured the operational VaR using four steps:

1. Define risk categories (processes, people, systems, or external events)
2. Measure risk factors (loss frequency defined as the number of loss events over a set time frame)
3. Measure exposure (loss severity defined as the monetary size of the loss once it occurs)
4. Calculate risk through operational value and expected loss (p.497)

Expected loss (EL) is how much an organization can expect to lose on average in daily activities. In terms of EVMS, EL is the amount lost as a result of required surveillance and follow-up actions caused by deficient guidelines. For example, EL is the government administrative costs of monitoring progress towards correcting a deficient contract and the time lost to developing and implementing a corrective action plan. Expected loss can be measured using the following equation:

$$EL = E(n) \times E(x) (1)$$

where

$E(n)$ = Loss frequency measured as the number of loss events over a time frame expressed as a decimal

$E(x)$ = Loss severity measured as the size of the loss once it occurs expressed in dollars

Both E(*n)* and E(*x*) are two loss distributions that are combined using the open form solutions method in which the mean of E*(n)* and E*(x)* are multiplied to get the mean of the aggregate loss distribution (Navarette, 2006). The mean of the aggregate loss distribution then becomes the expected loss.

$$EL = \text{Mean of } E(n) \text{ x Mean of } E(x) \; (2)$$

Taking the k^{th} percentile of the loss distribution or range of expected losses then becomes the operational VaR (Navarrete, 2006). Operational VaR can be calculated using the following equation:

$$\text{Operational VaR} = k^{th} \text{ Percentile of ELs} \; (3)$$

where

k^{th} *Percentile* = Confidence level

ELs = Loss Distribution /Range of Expected losses ($E(n) \times E(x)$)

The unexpected loss (*UL*) is the difference between the operational VaR and the expected loss. *UL* can bankrupt an institution and is the amount an organization should expect to insure for severe loss events (Navarrete, 2006). For EVMS, *UL* is the amount lost to the government caused by the potential severity a certain EVM deficiency can cause to the contract performance. *UL* can be calculated using the following equation:

$$UL = \text{Operational VaR} - EL \; (4)$$

Similarly, the expected and unexpected losses combined equal the operational VaR. For the contracting officer, *EL* can provide a VaR for expected costs caused by a significant deficiency such as administrative costs to monitor deficiencies. *UL* can provide the ACO with the additional VaR that the significant deficiency can cause in the most severe circumstances such as contract termination. Thus, the operational VaR can be summarized as such:

$$Operational\ VaR = UL + EL \quad (5)$$

Overall, Jorion's concept of the operational VaR can be used to determine the potential loss of a risky asset or in terms of the government, the potential loss in dollars of a major defense acquisition program (MDAP) regarding people, processes, systems, or events. A lack of compliance in the EVMS can be attributed to the operational risk of the EVM process; calculating the operational risk of an MDAP EVMS provides the government with a quantitative tool to measure EVMS risk. The frequency of deficient EVM guidelines can be collected using historical DCMA CAR data. Chapters IV and V will demonstrate that a severity analysis of the high risk guidelines will result in a rank order of severity for the 13 high risk guidelines. Last, the operational VaR would be able to provide contracting officers with a monetary risk amount that a deficient EVMS presents.

D. PAIRWISE COMPARISON

Pairwise comparison has been utilized for many years as a tool in rank ordering solutions for a given set of criteria. The basic principle of the method is to compare two solutions and award each solution with one point based on meeting the established criterion; the solution with the most points wins (Martin, 2011). Summers (2009) identified three steps in utilizing the pairwise comparison tool:

1. Create a table for each criterion that has the potential solutions listed in the first column and the first row.

2. Evaluate each of the solutions with respect to each criterion to determine if the row solution is better (+1 point), equivalent (0 point), or worse (-1 point) than the column solution.

3. Total the sum of all the solutions for each of the criteria.

Cost	**Honda Civic**	**Hyundai Elantra**	**Toyota Corolla**
Honda Civic		-1	+1
Hyundai Elantra	+1		+1
Toyota Corolla	0	-1	

MPG	**Honda Civic**	**Hyundai Elantra**	**Toyota Corolla**
Honda Civic		0	+1
Hyundai Elantra	0		+1
Toyota Corolla	-1	-1	

Power	**Honda Civic**	**Hyundai Elantra**	**Toyota Corolla**
Honda Civic		0	+1
Hyundai Elantra	0		+1
Toyota Corolla	-1	-1	

Criteria/Solutions	**Honda Civic**	**Hyundai Elantra**	**Toyota Corolla**
Cost	0	+2	-1
MPG	+1	+1	-2
Power	+1	+1	-2
Total Score	+2	+4	-5

Figure 1. Vehicle Pairwise Comparison Example

Figure 1 demonstrates that Hyundai Elantra with +4 points meets the majority of the set criteria. The drawback in using pairwise comparison is the inability to determine whether a solution has a higher weight over another (Summers, 2009). For our project, the pairwise comparison tool provides a structured and logical methodology by comparing one guideline criterion to another in order to determine the rank order severity of the 13 high risk guidelines.

E. SUMMARY

This chapter commenced with Fast (2012) suggesting that the operational VaR can be used to calculate risk in EVMSs. ACOs can utilize quantitative models in order to calculate a VaR amount that could justify withholding contractor progress payments. The operational VaR takes into consideration the frequency of a loss event occurring and the severity of the loss to calculate the VaR due to failures from people, processes, or systems. Implementing the operational VaR as a quantitative DoD risk model can provide contracting officers with a tool for payment withholds. Furthermore, the pairwise comparison provides a method to rank order the severity of the high risk guidelines that assist in calculating the severity of loss.

The next chapter, Methods of Analysis, describes the approach to collecting and analyzing our data.

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IV. METHODS OF ANALYSIS

A. ELECTRONIC CORRECTIVE ACTION REQUEST DATABASE

Collectable data on EVM deficiency reports, also known as CAR reports, serve as a key element for this research project. The DCMA manages the electronic Corrective Action Request (eCAR) database that consists of CAR reports ranging from levels I–IV. If a contractor is found deficient during their EVMS surveillance, DCMA ACOs must issue a CAR to the contractor and input the CAR report into the database for documentation. As a result, the DCMA has collected and organized deficiency reports (CAR reports) for over 200 contracts from 2007–2012. The e-CAR database organizes information in the following categories: date given to contractor, contracts by manufacturing facility also identified as Commercial and Government Entity (CAGE) codes, root cause of deficiencies, CAR level, and the deficient EVM guideline per contract. Most importantly, the database provided us with the frequency of deficient guidelines by CAGE code occurring within the past five years.

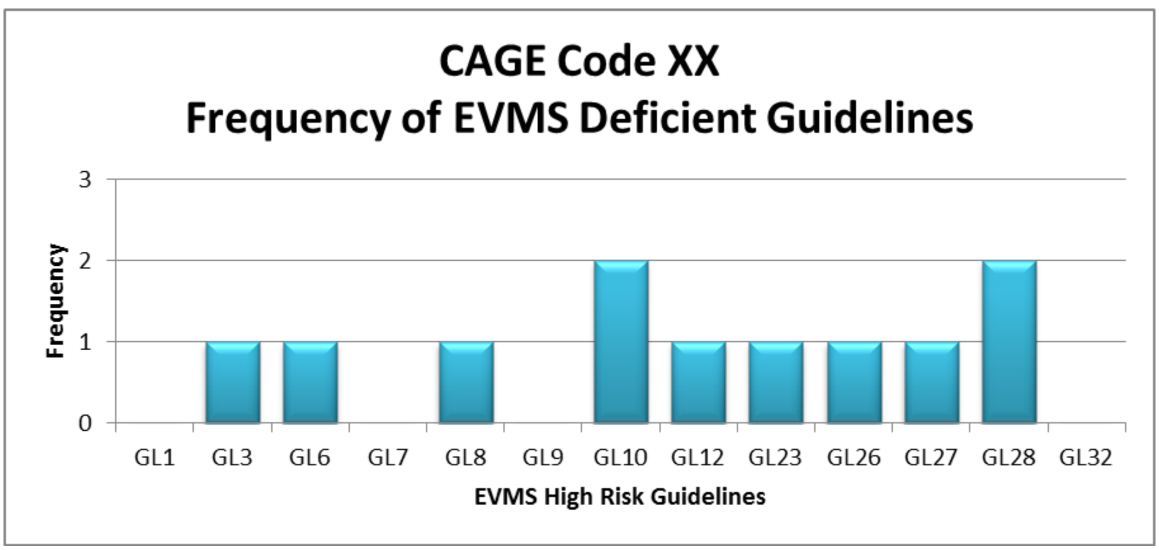

Figure 2. Example: CAGE Code XX Frequency of EVMS Deficient Guidelines

For confidential reasons, each CAGE code was recoded to keep company information anonymous. Figure 2 depicts an example of deficiencies that CAGE code XX received within the past five years. We chose to determine loss frequency by CAGE code because EVM systems are certified and validated by DCMA on a facility basis. The frequency of each guideline as shown in Figure 2 was divided by a total of 11deficiencies that spanned over five years for Facility XX. Table 3 below lists the calculated loss frequency percentage of each guideline expressed as a decimal. Depending on the total amount of deficiencies received at the facility, ACOs will obtain different loss frequency percentages for each CAGE code.

Table 3. Example: CAGE Code XX Loss Frequency %

EVMS Guideline	CAGE Code XX Frequency	Loss Frequency %
1	0	0.000
3	1	0.091
6	1	0.091
7	0	0.000
8	1	0.091
9	0	0.000
10	2	0.182
12	1	0.091
23	1	0.091
26	1	0.091
27	1	0.091
28	2	0.182
32	0	0.000

In the event Facility XX receives a first time deficiency in guideline 1, all loss frequency percentages as shown in Table 3 would change correspondingly based on a new total of 12 deficiencies.

B. METHOD FOR DETERMINING EVM GUIDELINE RANK ORDER

We evaluated the rank order of severity posed by the 13 high risk guidelines in three sequential stages. In the first stage, we rank ordered the four EVM groups and their respective guidelines from most severe to least severe, based on our analysis and supporting research.

Table 4. EVM Groups and Associated High Risk Guidelines

EVM Group	EVM Guidelines
Organization	1, 3
Planning, Scheduling, & Budgeting	6, 7, 8, 9, 10, 12
Analysis	23, 26, 27
Revisions	28, 32

Second, we conducted a pairwise comparison between the guidelines within each group resulting in a score of 1 if the given guideline was more severe than the other and a score of 0 for the less severe guideline. Table 4 outlines 20 pairwise guideline comparisons, which are segmented by their respective EVM group.

Table 5. 20 Pairwise Comparison Combinations of Guidelines

	Guideline	or	Guideline
Organization	1	or	3
Planning, Scheduling, & Budgeting	6	or	7
	6	or	8
	6	or	9
	6	or	10
	6	or	12
	7	or	8
	7	or	9
	7	or	10
	7	or	12
	8	or	9
	8	or	10
	8	or	12
	9	or	10
	9	or	12
	10	or	12
Analysis	23	or	26
	23	or	27
	26	or	27
Revisions	28	or	32

In the third stage, we obtained a total score for each guideline from the pairwise comparison method using Figure 2 as our score card. A point of 1 or 0 goes into each blank cell. Upon conclusion of the comparisons, points are totaled at the bottom row for the overall pairwise score.

Guidelines	1	3	6	7	8	9	10	12	23	26	27	28	32
1	-												
3		-											
6			-										
7				-									
8					-								
9						-							
10							-						
12								-					
23									-				
26										-			
27											-		
28												-	
32													-
Total Score													

Planning, Scheduling, & Budgeting

Analysis

Organization

Revisions

Figure 3. Pairwise Comparison Scorecard

Using Table 4 as a guide, we rank ordered each guideline within their respective groups based on their pairwise score. Next, we combined the ranking of the EVM groups and guidelines within each group to configure the overall ranking from 1 through 13, with 1 ranked as the most severe EVM guideline. For example, if the EVM group *Organization* is ranked as the most severe group and among its respective guidelines the pairwise comparison demonstrates that guideline 3 is more severe than guideline 1, the overall ranking results in guideline 3 as the most severe EVM guideline (rank 1 of 13). Similarly, if the EVM group *Revisions* is ranked as the least severe group of the four and among its respective guidelines the pairwise comparison demonstrates that guideline 28 is less severe than guideline 32, the overall ranking results in guideline 28 as the least severe EVM guideline (rank 13 of 13).

C. METHOD FOR DETERMINING THE GUIDELINE RISK FACTOR

Upon determining the overall ranking for the EVM guidelines, the risk factor for each guideline was assigned using the rank sum method. For research purposes and simplicity of assigning risk factors, we chose to use the rank sum method especially since we will be developing a rank order of severity for each of the 13 high risk guidelines.

However, DCMA officials or the ACO can utilize other methods to best fit their specific manufacturing facility or contract situation in determining the risk factor. For example, the risk factor can be determined using the direct assessment method in which the DCMA would subjectively assign the weighted risk for each deficient guideline depending on their assessment of guideline severity to their respective manufacturing facility. For example, the 1st six guidelines could be given an equal weight of 0.05 and the remaining seven guidelines could be given an equal weight of 0.10.

For this research project, the rank sum technique takes the sum of the ranks; in this case a ranking of 13 items (1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 + 11 + 12 + 13) provides a total sum of 91. To obtain the risk factor, each rank item is then divided by 91. The highest factor is assigned to rank 1 and each consecutive rank item is assigned to the next highest factor and so on. Table 6 outlines the rank sum method and corresponding risk factor. The risk factor can be a useful guide for ACOs in conducting and prioritizing surveillance activities. For example, higher risk factor items could warrant more frequent surveillance.

Table 6. Ranking and Risk Factors

Rank Item	**Rank Sum Calculation**	**Risk Factor**
1	13/91	0.143
2	12/91	0.132
3	11/91	0.121
4	10/91	0.110
5	9/91	0.099
6	8/91	0.088
7	7/91	0.077
8	6/91	0.066
9	5/91	0.055
10	4/91	0.044
11	3/91	0.033
12	2/91	0.022
13	1/91	0.011
Rank Item Sum: 91		**Total:** 1.00

D. SUMMARY

The eCAR database consisting of EVMS data for over 200 contracts covering the past five years is an essential source of data for our analysis and computation of the operational VaR. The eCAR database is critical to obtaining the loss frequency by CAGE code of the high risk guidelines, which is required for the application of the VaR model. Establishing the rank order of severity for the EVM guidelines was conducted in three stages: rank ordering the EVM group, utilizing pairwise comparison to rank order the guidelines within each group, and then combining both EVM group and guideline rankings to obtain the overall ranking from 1 to 13. The risk factors for each rank item were established using the rank sum methodology. However, DCMA officials have the discretion to use other methodologies that best meet their specific facility to obtain the risk factors, which can be used by ACO’s to prioritize surveillance activities.

The next chapter, *Analysis and Results*, reveals the rank order of severity for each high risk guideline and the application of the operational VaR to EVMS.

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V. ANALYSIS AND RESULTS

A. SEVERITY ANALYSIS OF EVMS GROUPS & GUIDELINES

In this section, we discuss our findings on the rank order of severity analysis for the 13 EVMS high risk guidelines. The rank order of severity can assist ACO's in prioritizing surveillance activities by focusing limited resources on essential high risk guidelines. First, we discuss our analysis in determining the EVMS group rank order of severity. Second, we describe the reason for our selection in each of the 20 pairwise comparison combinations of the high risk EVMS guidelines.

1. EVMS Groups

As described in the introduction, EVM measures a program's cost, schedule, and performance by identifying measures to ensure a program is in accordance with ANSI/EIA 748 standards and on track for success. Each of the 13 guidelines belong to one of the four EVMS groups covered in this project. Table 7 outlines the cluster of guidelines by group, which were ranked from most severe rank 1 to least severe rank 4.

Table 7. EVMS Group Ranking

Rank Order	EVMS Group	EVMS Guidelines
1	Planning, Scheduling, & Budgeting	6, 7, 8, 9, 10, 12
2	Analysis	23, 26, 27
3	Organization	1, 3
4	Revisions	28, 32

The following demonstrates our reasoning for each EVMS group ranking.

- Rank 1: Planning, Scheduling, & Budgeting

We ranked this group as most severe because establishing a PMB is the core function of this group, which is also what EVM data are measured against to monitor program progress and risk mitigation. This group function schedules authorized work and applies the right amount of resources to appropriately budget the program; these measures feed into establishing the PMB (Government Accountability Office [GAO], 2009). Common root causes of poor program performance include issues with the schedule guidelines within this group, such as too many activities scheduled with unrealistic timeframes. Additionally, the eCAR database demonstrates that the sum amount of frequencies from this group equate to 48.2% of the total frequencies caused by the 13 high risk guidelines. Failure to properly plan, schedule, authorize work, determine a budget, and develop a PMB results in significant deficiencies by which the program will have no baseline to monitor progress. The functions of this group must be established first before the program can proceed further.

- Rank 2: Analysis

Analysis was ranked as the second most severe group because it requires identification and analysis of cost and schedule variances. Analyzing any variance within the program is critical to developing a corrective plan of action to mitigate any severe consequences. This functional group requires analysis of the reporting measures for EVM such as cost variances (CV), schedule variance (SV), or estimate at completion (EAC), which are critical indicators of program performance. Furthermore, data accuracy is a common indicator of poor program performance. Issues such as lack of planning for corrective actions, multiple data input errors, and various reasons for variances play a role in ensuring that the guidelines within this group are implemented to standard. Additionally, the eCAR database demonstrates that the sum amount of frequencies from this group equates to 26.6% of the total frequencies caused by the 13 high risk guidelines. This group requires routine evaluation of the PMB and PMS as a safeguard against not meeting critical deliverables and milestones. Upon establishing a PMB and PMS, routine analytical evaluation is essential to monitoring EVMS data for accuracy and program success.

- Rank 3: Organization

The third most severe group is organization, which defines the scope of the WBS and organizational responsibilities for each WBS package. Upon authorizing the WBS to include ensuring accurate data analysis of the authorized work, the organization group defines the range of requirements for the program and integrates the cost and scheduling data into an organizational structure. Additionally, the eCAR database demonstrates that the sum amount of frequencies from this group equates to 13.9% of the total frequencies caused by the 13 high risk guidelines. Organization of authorized work that is accurately analyzed is essential prior to commencing a project.

- Rank 4: Revisions

We ranked the revision group as least severe because the requirements of this group are implemented after a PMB is established, data accuracy is evaluated, and organizations of WBS packages are conducted. Revisions are a mechanism to document and manage changes in a timely manner. Additionally, the eCAR database demonstrates that the sum amount of frequencies from this group equates to 11.1% of the total frequencies caused by the 13 high risk guidelines. This group is ranked last because the sequential order of the guidelines within this group can only be conducted after the requirements in the other three groups are executed.

2. EVMS Guidelines

The pairwise comparison combinations are only between guidelines (GLs) within the same group. Thus, our rank order analysis is limited to only ranking guidelines based on the rank of their respective EVM group. For example, GL 1 could be ranked within the top five GLs in terms of most severe; however, because GL 1 belongs to the organization group, which is ranked 3, its overall rank might be 10 of 13.

Each pairwise combination was compared based on selecting the guideline that posed a higher risk defined as a measure of future uncertainties in achieving program performance goals within defined cost and schedule constraints. Each guideline (significant deficiency) was evaluated in terms of severity, which is the consequence of the future occurrence of that significant deficiency. The following sections discuss the reasoning for each selected EVM GL that obtained a total score of 1 or higher as shown in Figure 4:

Guidelines	1	3	6	7	8	9	10	12	23	26	27	28	32
1	-	0		Planning, Scheduling, & Budgeting									
3	1	-											
6			-	0	1	0	0	0		Analysis			
7			1	-	1	0	0	0					
8			0	0	-	0	0	0					
9	Organization		1	1	1	-	1	0				Revisions	
10			1	1	1	0	-	0					
12			1	1	1	1	1	-					
23									-	0	0		
26									1	-	0		
27									1	1	-		
28												-	0
32												1	-
Total Score	1	0	4	3	5	1	2	0	2	1	0	1	0

Figure 4. Pairwise Comparison Scores

a. EVM Guideline 1: Define Authorized Work

In this comparison, GL 1 is compared with GL 3 as shown in Table 8. We selected GL 1 as more severe based on defining the range of requirements for work using the WBS. For tables 8 through 16, the highlighted GL is more severe when comparing between the two GLs.

Table 8. GL 1 vs. GL 3

Pairwise Comparison	Selected	EVM Guidelines
1	X	GL 1 Define Authorized Work (WBS Elements)
		GL 3 Integrate the System

The WBS is an essential component of EVM and the basis to correlate estimated costs and schedule with actual costs (GAO, 2009). A program must have an organized WBS structure before integration of the system can take place as stated in GL 3. EVM criterion 3 integrates all system inputs such as costs, schedules, deliverables, and the WBS structure to include identifying team roles and responsibilities. For example, the F-22 Spiral 2 case study showed that the integrated master schedule (IMS) and cost estimates were tied to the Spiral 2 WBS, for without the WBS, the F-22 team would not be able to integrate the critical inputs (Dibert & Velez, 2006). Additionally, the WBS is essential to developing the PMB which EVM data for the program are measured against. Since the PMB serves as the baseline for measuring EVM, deficiencies in this GL are linked with deficiencies in GLs 1 and 6. In order to develop a well-defined PMB, there should not be a deficiency in GL 1 (development of WBS) or 6 (scheduling authorized work) because both are required to develop the PMB.

b. EVM Guideline 6: Schedule the Work

Table 9 shows the pairwise comparisons in which GL 6 was selected as more severe than GLs 7, 9, 10, and 12.

Table 9. GL 6 vs. GLs 7, 9, 10, and 12

Pairwise Comparison	Selected	EVM Guidelines
2	X	GL 6 Schedule the Work
		GL 7 Identify Products, Milestones, and Indicators
3	X	GL 6 Schedule the Work
		GL 9 Establish Budgets for Work
4	X	GL 6 Schedule the Work
		GL 10 Identify Work Packages
5	X	GL 6 Schedule the Work
		GL 12 Identify and Control Level of Effort

EVM criterion 6 was selected as more severe based on developing a PMS, which serves as the source for scheduling authorized work. Failure to accurately establish critical milestone dates in an organized manner highly impacts the scheduling variance. In the F-22 case, the PM established a detailed PMS; however, constantly changing requirements made adhering to the schedule difficult (Dibert & Velez, 2006). The numerous changes created a negative domino effect for the integrated product team (IPT) responsible for developing the work package activity schedules (Dibert & Velez, 2006). Scheduling the work feeds into the schedule variance (SV), which is a direct EVM measure of success and a deciding factor towards maintaining or canceling a program. The authorized work must be scheduled before the budget or work packages can be established to include LOE activities as described in GLs 9, 10, and 12.

c. EVM Guideline 7: Identify Products, Milestones, and Indicators

Table 7 shows that the following pairwise comparisons identified GL 7 as more severe than GLs 9, 10, and 12. GL 7 describes the tangible products to be developed in accordance with the established schedule.

Table 10. GL 7 vs. GLs 9, 10, and 12

Pairwise Comparison	Selected	EVM Guidelines
6	X	GL 7 Identify Products, Milestones, and Indicators
		GL 9 Establish Budgets for Work
7	X	GL 7 Identify Products, Milestones, and Indicators
		GL 10 Identify Work Packages
8	X	GL 7 Identify Products, Milestones, and Indicators
		GL 12 Identify and Control Level of Effort

We found GL 7 to be more severe than its opponents due to the difficulty in measuring the products in terms of value. Furthermore, contractors must clearly identify the completed phase of the physical product in accordance with the schedule (Fleming & Koppelman, 2012). GL 7 is a challenging criterion to meet especially in the field of software development because both the government and contractor must agree on the value that each product possesses, which can be complex to measure. In the F-22 case study, Lockheed Martin experienced difficulty in developing new software, which led to problems in identifying the measure of success for this portion of the program. Furthermore, F-22 issues within this criterion resulted in special emphasis from the government. The requirements as established in GL 7 are linked to GLs 6 and 12 in that identifying the products must be in accordance with scheduling milestones and LOE activities must be identified during the activities of this phase as well.

d. EVM Guideline 8: Plan the Performance Measurement Baseline

In the following comparisons, GL 8 obtained a total score of 5 for being selected as more severe than GLs 6, 7, 9, 10, and 12 as shown in Table 11.

Table 11. GL 8 vs. GLs 6, 7, 9, 10, and 12

Pairwise Comparison	**Selected**	**EVM Guidelines**
9		GL 6 Schedule the Work
	X	GL 8 Plan the Performance Measurement Baseline
10		GL 7 Identify Products, Milestones, and Indicators
	X	GL 8 Plan the Performance Measurement Baseline
11	X	GL 8 Plan the Performance Measurement Baseline
		GL 9 Establish Budgets for Work
12	X	GL 8 Plan the Performance Measurement Baseline
		GL 10 Identify Work Packages
13	X	GL 8 Plan the Performance Measurement Baseline
		GL 12 Identify and Control Level of Effort

EVM GL 8 serves as the most severe criterion based on the critical function of the PMB. The PMB establishes a framework to measure and monitor EVM of cost, schedule, and performance of a program (Fleming & Koppelman, 2012). The PMB develops the budget and funds the scheduled work authorized for the program. PMB integrates schedule and cost into one baseline. Measurements outside of the baseline signal focus areas for the program management team. A common indicator of poor performance is in developing PMBs in which budgets are unequally distributed to earlier scheduled tasks, thus concealing issues until it is too late to fix them (GAO, 2009). DCMA EVM specialists have stated that contractors tend to only create a PMB constructed on the base year rather than the life cycle of the program due to the current budget appropriations. This major issue likely leads to cost overruns and can severely affect the credibility of program officials and put the program at high risk for cancellation (GAO, 2009). Furthermore, without a well-developed PMB, there is no foundation or reference point to measure EVM data against performance.

e. EVM Guideline 9: Establish Budgets for Work

In this comparison, GL 9 is selected as more severe than GL 12 because it involves establishing budgets for the authorized work.

Table 12. GL 9 vs. GL 12

Pairwise Comparison	Selected	EVM Guidelines
14	X	GL 9 Establish Budgets for Work
		GL 12 Identify and Control Level of Effort

This guideline requires an appropriate amount of funding as negotiated for the program; however, program teams tend to obligate any excess funds for another element of the program. The severity involved in inappropriately allocating funds elsewhere leads to a deficiency and may likely affect funding in later phases such as integration and testing (GAO, 2009). Excess funding should be placed in management reserve (MR) to mitigate future budgeting risks. Establishing budgets appropriately from the beginning is crucial to how the program is able to mitigate financial risks throughout the life cycle of the program.

f. EVM Guideline 10: Identify Work Packages

Table 13 demonstrates that GL 10 was selected as more severe in comparison with GLs 9 and 12 because it involves identifying work packages based on the WBS in terms of budgets, hours, and other EVM numerical measures for the near and long term (Fleming & Koppelman, 2012).

Table 13. GL 10 vs. GLs 9 and 12

Pairwise Comparison	Selected	EVM Guidelines
15		GL 9 Establish Budgets for Work
	X	GL 10 Identify Work Packages
16	X	GL 10 Identify Work Packages
		GL 12 Identify and Control Level of Effort

Before one can establish a budget, the work package measures must be identified to include establishing an MR for future uncertainties. In the F-22 case, work packages especially outside of the current year were difficult to identify due to the constantly changing requirements. Likewise, because criterion 12 involves identifying LOE activities that measure time rather than tangible products that can be measured using EVM, it was rated as the least severe in this EVM group. LOE activities provide no value to EVM because they do not contribute to measuring SV or CV; however, LOE activities must be identified to ensure PMs do not account for this as EVM measurements.

g. EVM Guideline 23: Analyze Schedule and Cost Variances

As shown in Table 14, GL 23 was selected as more severe in comparison with GLs 26 and 27.

Table 14. GL 23 vs. GLs 26 and 27

Pairwise Comparison	Selected	EVM Guidelines
17	X	GL 23 Analyze Schedule and Cost Variances
		GL 26 Implement Managerial Actions
18	X	GL 23 Analyze Schedule and Cost Variances
		GL 27 Develop Revised Estimates of Cost at Completion

We based our decision on the importance of accurately identifying EVM data such as variances in cost and schedule. The EVM data obtained in this criterion are critical to measuring the health status of a program (GAO, 2009). Furthermore, by requiring a thorough analysis of the causes for exceeding a given threshold, management can better develop a course of action to fix the variances. GL 23 provides the data to measure program status, for without it, there is no EVM to measure, thus defeating the purpose and benefits of the EVMS.

h. EVM Guideline 26: Implement Managerial Actions

In this comparison, Table 15 shows that GL 26 was selected as more severe than GL 27.

Table 15. GL 26 vs. GL 27

Pairwise Comparison	**Selected**	**EVM Guidelines**
19	X	GL 26 Implement Managerial Actions
		GL 27 Develop Revised Estimates of Cost at Completion

Although common indicators of poor performance show frequent deficiencies in revising and updating EACs in accordance with the PMB as described in GL 27, implementing managerial actions as described in GL 26 affects how EACs are updated. In the F-22 case, GL 26 was rated as insufficient for failure to take necessary actions to realign the program based on the variances, which led to inaccurate EACs (Dibert & Velez, 2006). EACs must be compared to the PMB on a continual basis, but if the necessary managerial actions are not taken to reconfigure the PMB based on any schedule and cost variances, EACs are to be calculated accurately. GAO (2009) showed that many programs tend to develop overly optimistic EACs, have no reasonable plan to achieve the EAC, and fail to account for risks. The eCAR database shows that GL 27 is the most frequent deficiency at 13.7% for all 13 EVM guidelines. Given that GL 27 is highest rate of deficiency clearly shows the importance of ensuring GL 23 and 26 are implemented correctly to prevent deficiencies in GL 27. Failure to implement corrective actions result in poorly defined EACs; therefore, GL 26 poses a higher risk in severity.

i. EVM Guideline 28: Incorporate Changes into Plans, Budgets, and Schedules

In our last comparison, we chose GL 28 to be more severe in consequence than GL 32. The intent of GL 28 is to realistically update the PMB so that frequent changes to program are prevented. Incorporating the changes in a timely manner ensures that execution of changes is implemented. On the other hand, documenting the changes sequentially through tracking a record as described in GL 32 should occur once the changes are incorporated. We found GL 32 to be more a routine administrative function that bears less risk if not executed.

Table 16. GL 28 vs. GL 32

Pairwise Comparison	Selected	EVM Guidelines
20	X	GL 28 Incorporate Changes into Plans, Budgets, and Schedules
		GL 32 Document Changes to the PMB

B. RANK ORDER RESULTS

Upon ranking the four EVMS groups and conducting the pairwise comparison of the EVMS guidelines within their respective groups, we used the pairwise scores to determine the overall ranking for all 13 EVMS high risk guidelines ranking each guideline from 1 as most severe to 13 as least severe. Table 7 illustrates the results of the guideline pairwise score and rank order.

Table 17. EVMS Guideline Pairwise Score and Rank Order

EVM Rank Order	Group Ranking	Guidelines	Pairwise Score
# 1	# 1. Planning, Scheduling, & Budgeting	8	5
# 2		6	4
# 3		7	3
# 4		10	2
# 5		9	1
# 6		12	0
# 7	# 2. Analysis	23	2
# 8		26	1
# 9		27	0
# 10	# 3. Organization	1	1
# 11		3	0
# 12	# 4. Revisions	28	1
# 13		32	0

Based on our analysis in the previous section and implementation of our rank order methodology, Table 18 lists the overall rank order of severity for the 13 EVMS high risk guidelines.

Table 18. Overall Rank Order of Severity

Rank Order	EVMS High Risk Guidelines
# 1	GL 8
# 2	GL 6
# 3	GL 7
# 4	GL 10
# 5	GL 9
# 6	GL 12
# 7	GL 23
# 8	GL 26
# 9	GL 27
# 10	GL 1
# 11	GL 3
# 12	GL 28
# 13	GL 32

The rank order of severity provides a means for the ACO and his or her staff to focus their limited resources on the surveillance of high risk guidelines. For example, Table 18 suggests that GL 8 is a high risk priority and surveillance should be conducted weekly verses quarterly for a less severe guideline such as GL 32.

C. APPLICATION OF THE OPERATIONAL VAR MODEL TO EVMS

As discussed in Chapter III, the operational VaR is the recommended quantitative model to calculate risk for a given contract with significant EVMS deficiencies. This section discusses the application of the operational VaR model for two different deficient EVMS scenarios. For both examples, we chose to calculate the VaR using the 95%, 99%, and 99.9% confidence levels based on historical VaR applications demonstrating that financial risk analysis generally ranges from 95% to 99.9% (Navarrete, 2006). However, the DCMA personnel have the discretion to set the confidence level intuitively based on the government's best interest and specific contract situation.

In calculating the loss frequency of each deficient guideline, we used the eCAR database to obtain the number of deficient GLs by CAGE code per year. Given the data, we developed a modified method to obtain the loss frequency in the future. Our modified method to obtain the loss frequency consisted of multiplying the time factor by the CAR weight:

$$E(n) = \text{Time Factor x CAR Weight (6)}$$

where

Time Factor = (CARs per year x Time Remaining on Contract) (7)

The number of CARs per year was calculated by dividing the total deficiencies by the number of year(s) CARs were received. The CAR weight was determined using the eCAR database of the frequency of deficiencies by CAGE code per year and obtaining a probability.

In determining the loss severity, we chose to use both the DCMA and contractor's administrative and labor costs involved in investigating and determining the root cause of a deficiency and processing a CAR. The costs of pursuing a CAR involve preparing the corrective action plan; implementing the corrective action plan; independent validation that corrective actions were actually taken; revalidation of the EVMS (if necessary); and closing out the CAR. Since EVM is applied to all incentive and cost type contracts valued at $20 million or above, the costs to run the EVMS and associated costs to correct significant EVMS guideline deficiencies can be passed by the contractor to the government as allowable costs.

In addition, any cost overruns or cost variance (CV) that a specific deficiency caused to the contractor and government would also be taken into the loss severity calculation. The administrative costs of fixing a CAR and cost overruns if applicable would show that more costs were spent for work accomplished than was planned, which represents risk to the government. Because we did not have data on CAR severity costs, we used fictitious severity data for both EVMS examples.

The operational VaR to the government consist of both EL and UL at a given confidence interval, which covers the government's expected losses and severe unexpected losses from a deficient guideline(s). Figure 5 depicts Navarette's (2006) illustration of how both EL and UL at the 99.9% confidence level make up the operational VaR and the dollar amount of risk the government suffers as a result of the deficiencies.

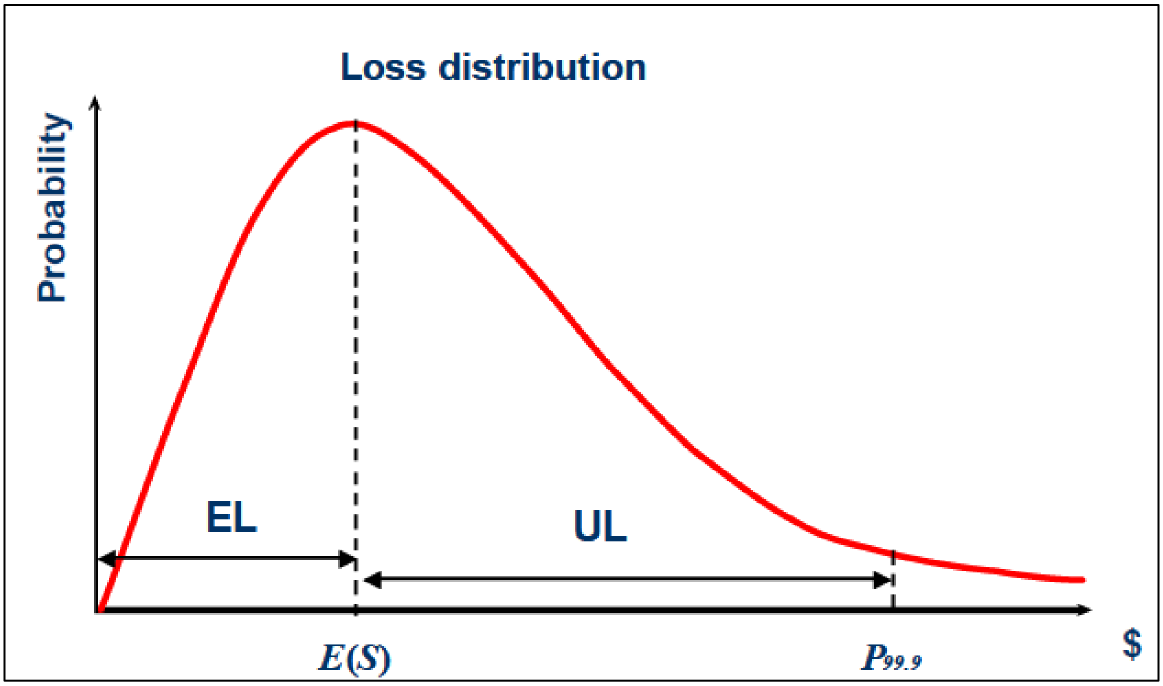

Figure 5. EL, UL, Operational VaR (from Navarette, 2006)

Each example follows these nine steps:

1. Calculate the CAGE Code CAR weight for each guideline. Add the new guideline deficiency to the current amount of guideline deficiencies, then divide by the updated total amount of deficiencies from each guideline.

CAR Weight$_1$ =

<u>(Current Guideline Frequency + New Guideline Frequency)</u>

Total Amount of Frequencies from each Guideline (8)

2. Calculate the time factor. Determine the CARs per year (total amount of CARs divided by total amount of years CARs received) multiplied by the time remaining on contract (equation 7).

Time Factor = (CARs per year x Time Remaining on Contract) (9)

3. Calculate E(n), the loss frequency by multiplying the time factor by each CAR weight.

$$E(n)_1 = \text{Time Factor x CAR Weight (10)}$$

4. Obtain $E(x)_1$, the loss of severity. Use the administrative and labor costs required to process each deficient guideline and cost overruns, if applicable, caused by the guideline deficiency.

5. Calculate EL_1 for each guideline deficiency, Multiply equation (10) by $E(x)_1$ to obtain the *EL* value for each guideline.

$$EL_1 = E(n)_1 \times E(x)_1 \text{ (11)}$$

6. Calculate the overall EL. Multiply the mean of E(*n*) and E(*x*).

$$\textit{Overall EL = Mean of E(x) x Mean of E(n)} \text{ (12)}$$

7. Calculate the operational VaR. Take the percentile (established confidence level) of the loss distribution (range of *EL*s). For our research, we calculated the 95^{th}, 99^{th}, and 99.9^{th} percentile using the Microsoft Excel PERCENTILE.INC function.

$$\text{Operational VaR = Percentile Range of EL(s) (13)}$$

8. Calculate the overall *UL*. Subtract the Overall *EL* from the operational VaR.

$$\text{Overall } UL = \text{Operational VaR – Overall } EL \text{ (14)}$$

9. The withhold amount caused by the deficiencies is the calculated operational VaR not to exceed the maximum 5% of contractor progress payments.

1. Scenario 1: CAGE Code XX

In Scenario 1, CAGE code XX or Contract XX has been issued a CAR Level III with the following repeated EVMS guideline deficiencies: 3, 6, 10, 12, 23, and 27. Using unidentified EVM data from the Defense Cost and Resource Center (DCARC) database, Table 19 outlines pertinent EVM data for Scenario 1 with guideline severity costs and any cost overruns as a result of the CAR.

Table 19. Scenario 1 Information

Scenario 1: CAGE Code XX			
Duration (Mo.)	62	**Time Remaining on Contract (Mo.)**	24
Budget at Completion (BAC)	$ 729,000,000.00	**Total Years of CARs Received**	5
*** Calculated Progress Payments $ per month**	$ 11,758,064.52	**Max Withhold Amount $ per month**	$ 587,903.23
	GL Severity Dollars		
EVMS Deficient Guidelines	**Administrative $ Costs**	**Overrun $ Costs**	**Total $ Loss Severity E(x)**
3	$ 75,000.00	$ 400,000.00	$ 475,000.00
6	$ 110,000.00	$ 300,000.00	$ 410,000.00
10	$ 50,000.00	$ 200,000.00	$ 250,000.00
12	$ 20,000.00	$ 0	$ 20,000.00
23	$ 40,000.00	$ 600,000.00	$ 640,000.00
27	$ 95,000.00	$ 1,200,000.00	$ 1,295,000.00

*Calculated using BAC divided by duration

Executing the nine steps, the operational VaR for the six EVMS deficiencies is calculated as such:

1. Calculate the CAGE Code CAR weight for each guideline. Add the new guideline deficiency to the current amount of guideline deficiencies, then divide by the updated total amount of deficiencies from each guideline.

Table 20 illustrates that guidelines 3, 6, 10, 12, 23, and 27 are repeated deficiencies, which caused their respective CAR weight percentages to change.

Table 20. Scenario 1: Step 1 Calculations

EVMS Guideline	**“Current” Cage Code XX Frequency**	**CAR Weight**	**“New” Cage Code XX Frequency**	**New CAR Weight**
1	0	0.000	0	0.000
3	1	0.091	2	0.118
6	1	0.091	2	0.118
7	0	0.000	0	0.000
8	1	0.091	1	0.059
9	0	0.000	0	0.000
10	2	0.182	3	0.176
12	1	0.091	2	0.118
23	1	0.091	2	0.118
26	1	0.091	1	0.059
27	1	0.091	2	0.118
28	2	0.182	2	0.118
32	0	0.000	0	0.000
Total Deficiencies	11	**New Total Deficiencies**	17	

2. Calculate the time factor. Determine the CARs per year (total amount of CARs divided by total amount of years CARs received) multiplied by the time remaining on contract (equation 7).

Table 21. Scenario 1: Step 2 Calculations

CARs per year = (Total Amount of CARS) / (Total Years of CARs Received)			
Total Amount of CARS Received	**Total Years of CARs Received**	**CARs per year**	**Time Remaining on Contract (yrs)**
17	5	3.4	2
Time Factor (CARs per year X Time Remaining on Contract)			6.8

3. Calculate E(n), the loss frequency by multiplying the time factor by each CAR weight. CAR weights were taken from the calculations in Table 20.

Table 22. Scenario 1: Step 3 Calculations

	E(n) = Time Factor x CAR Weight		
EVMS Deficient Guidelines	**Time Factor**	**CAR Weight**	**Loss Frequency E(n)**
3	6.8	0.118	0.80
6	6.8	0.118	0.80
10	6.8	0.176	1.20
12	6.8	0.118	0.80
23	6.8	0.118	0.80
27	6.8	0.118	0.80

4. Obtain $E(x)_1$, the loss of severity. Use the administrative and labor costs required to process each deficient guideline and cost overruns, if applicable, caused by the guideline deficiency. See Table 19.

5. Calculate EL_1 for each guideline deficiency by multiplying equation (10) by $E(x)_1$ to obtain the EL value for each guideline. Loss severity and loss frequency data obtained from Tables 19 and 22 respectively.

Table 23. Scenario 1: Steps 4–6 Calculations

	EL = E(x) x E(n)		
EVMS Deficient Guidelines	**Loss Severity *E(x)***	**Loss Frequency *E(n)***	**Expected Loss (EL)**
3	$ 475,000.00	0.80	$ 381,140.00
6	$ 410,000.00	0.80	$ 328,984.00
10	$ 250,000.00	1.20	$ 299,200.00
12	$ 20,000.00	0.80	$ 16,048.00
23	$ 640,000.00	0.80	$ 513,536.00
27	$ 1,295,000.00	0.80	$ 1,039,108.00
Mean of E(x)		**Mean of E(n)**	
$ 515,000.00		0.87	
Mean of E(x) x Mean of E(n)			
Overall EL		$448,050.00	

6. Calculate the overall EL. Multiply the mean of E(n) and E(x). See Table 23.

7. Calculate the operational VaR, Take the percentile (established confidence level) of the loss distribution (range of ELs). For our research, we calculated the 95th, 99th, and 99.9th percentile using the Microsoft Excel PERCENTILE.INC function. See Figure 6 and Table 24.

Table 24. Scenario 1: Step 7 Calculations

EVMS Deficient Guidelines	Loss Severity *E(x)*	Loss Frequency *E(n)*	Expected Loss (EL)
3	$ 475,000.00	0.80	$ 381,140.00
6	$ 410,000.00	0.80	$ 328,984.00
10	$ 250,000.00	1.20	$ 299,200.00
12	$ 20,000.00	0.80	$ 16,048.00
23	$ 640,000.00	0.80	$ 513,536.00
27	$ 1,295,000.00	0.80	$1,039,108.00
Mean of E(x)		**Mean of E(n)**	
$ 515,000.00		0.87	
Mean of E(x) x Mean of E(n)			
Overall EL		$448,050.00	

Take the 95th, 99th, and 99.9th Percentile of the Loss Distribution (range of ELs) using the Microsoft Excel Percentile Function

Table 25. Scenario 1: Steps 7–8 Calculations

Percentiles		**Losses**	
Confidence Level	**Operational VaR (Percentile of Loss Distribution)**	**Overall EL (Aggregate Loss Distribution)**	**Overall UL (Operational VaR - EL)**
95.00%	$ 907,715.00	$ 448,050.00	$ 459,665.00
99.00%	$ 1,012,829.40	$ 448,050.00	$ 564,779.40
99.90%	$ 1,036,480.14	$ 448,050.00	$ 588,430.14

8. Calculate the overall UL. Subtract the overall EL from the operational VaR. See Table 24 for calculations. Figure 7 is a depiction of the loss distribution at the 95th percentile that shows how the overall EL and UL equate to the operational VaR.

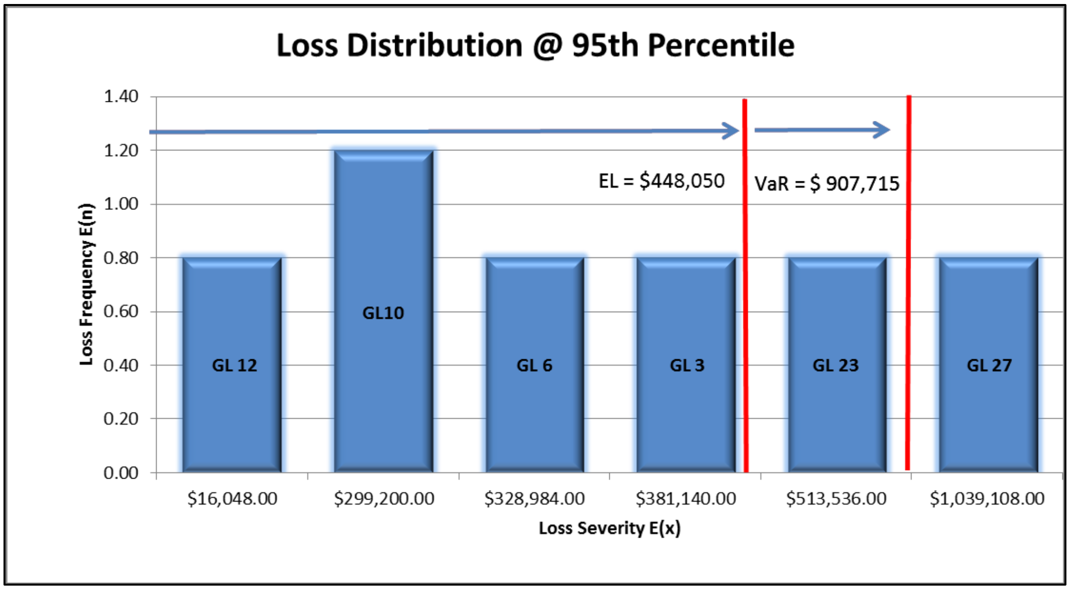

Figure 6. Scenario 1: Loss Distribution Chart at 95th Percentile

9. The withhold amount caused by the deficiencies is the calculated operational VaR not to exceed the maximum 5% of contractor progress payments.

Table 26. Scenario 1: Total VaR and Withhold Amount Determination

VaR at 95% Confidence Level	$ 907,715.00
Monthly Progress Payments	$11,758,064.52
Monthly Maximum Withhold Amount	$ 587,903.23
Final Amount to Withhold	$ 587,903.23

Scenario 1 shows that the total operational VaR for EVMS guideline deficiencies (3, 6, 10, 12, 23, and 27) is approximately $908,000. The monetary risk caused by the EVMS deficiencies exceeds the maximum monthly withhold amount of approximately $600,000. The severity of the six EVMS deficiencies for Contract XX were equal to a progress payment withhold of 7.7%, which exceeds the statutory limit of withholding a maximum 5% of progress payments.

2. Scenario 2: CAGE Code YY

In Scenario 2, CAGE code YY or Contract YY has been issued a CAR Level III with never before seen EVMS guideline deficiencies 1and 32. Using unidentified EVM data from the Defense Cost and Resource Center (DCARC) database, Table 26 outlines pertinent EVM data for Scenario 2 with guideline severity costs and any cost overruns as a result of the CAR.

Table 27. Scenario 2 Information

Scenario 2: CAGE Code YY			
Duration (Mo.)	41	**Time Remaining on Contract (Mo.)**	24
Budget at Completion (BAC)	$ 198,000,000.00	**Total Years of CARs Received**	2
*** Calculated Progress Payments $ per month**	$ 4,829,268.29	**Max Withhold Amount $ per month**	$ 241,463.41
	GL Severity Dollars		
EVMS Deficient Guidelines	**Administrative $ Costs**	**Overrun $ Costs**	**Total $ Loss Severity E(x)**
1	$ 60,000.00	$ 160,000.00	$ 220,000.00
32	$ 15,000.00	$ -	$ 15,000.00

*Calculated using BAC divided by duration

Executing the nine steps, the operational VaR for the two EVMS deficiencies is calculated as such:

1. Calculate the CAGE Code CAR weight for each guideline. Add the new guideline deficiency to the current amount of guideline deficiencies, then divide by the updated total amount of deficiencies from each guideline.

Table 27 illustrates that guidelines 1 and 32 are never before seen deficiencies, which caused their respective CAR weight percentages to change.

Table 28. Scenario 2: Step 1 Calculations

EVMS Guideline	"Current" Cage Code XX Frequency	CAR Weight	"New" Cage Code XX Frequency	New CAR Weight
1	0	0.000	1	0.167
3	1	0.250	1	0.167
6	0	0.000	0	0.000
7	0	0.000	0	0.000
8	0	0.000	0	0.000
9	1	0.250	1	0.167
10	0	0.000	0	0.000
12	0	0.000	0	0.000
23	0	0.000	0	0.000
26	0	0.000	0	0.000
27	1	0.250	1	0.167
28	1	0.250	1	0.167
32	0	0.000	1	0.167
Current Total Deficiencies	4	**New Total Deficiencies**	6	

2. Calculate the time factor. Determine the CARs per year (total amount of CARs divided by total amount of years CARs received) multiplied by the time remaining on contract (equation 7).

Table 29. Scenario 2: Step 2 Calculations

CARs per year = (Total Amount of CARS) / (Total Years of CARs Received)			
Total Amount of CARS Received	**Total Years of CARs Received**	**CARs per year**	**Time Remaining on Contract (yrs)**
6	2	3	2
Time Factor (CARs per year X Time Remaining on Contract)			6

3. Calculate E(n), the loss frequency. Multiply the time factor by each CAR weight. CAR weights were taken from the calculations in Table 27.

Table 30. Scenario 2: Step 3 Calculations

	E(n) = Time Factor x CAR Weight		
EVMS Deficient Guidelines	**Time Factor**	**CAR Weight**	**Loss Frequency E(n)**
1	6	0.167	1.002
32	6	0.167	1.002

4. Obtain $E(x)_1$, the loss of severity, use the administrative and labor costs required to process each deficient guideline and cost overruns, if applicable, caused by the guideline deficiency. See Table 26.

5. Calculate EL_1 for each guideline deficiency. Multiply equation (10) by $E(x)_1$ to obtain the EL value for each guideline. Loss severity and loss frequency data obtained from Tables 26 and 29 respectively.

Table 31. Scenario 2: Steps 4–6 Calculations

	EL = E(x) x E(n)		
EVMS Deficient Guidelines	**Loss Severity *E(x)***	**Loss Frequency *E(n)***	**Expected Loss (EL)**
1	$ 220,000.00	1.002	$ 220,440.00
32	$ 15,000.00	1.002	$ 15,030.00
Mean of E(x)		**Mean of E(n)**	
$ 117,500.00		1.002	
Mean of E(x) x Mean of E(n)			
Overall EL		$117,735.00	

6. Calculate the overall EL. Multiply the mean of E(n) and E(x). See Table 30.

7. Calculate the operational VaR. Take the percentile (established confidence level) of the range of EL(s). For our research, we calculated the 95th, 99th, and 99.9th percentile using the Microsoft Excel PERCENTILE.INC function. See Figure 7 and Table 31.

EVMS Deficient Guidelines	**Loss Severity *E(x)***	**Loss Frequency *E(n)***	**Expected Loss (EL)**
1	$ 220,000.00	1.002	$ 220,440.00
32	$ 15,000.00	1.002	$ 15,030.00

Take the 95th, 99th, and 99.9th Percentile of the Loss Distribution (range of ELs) using the Microsoft Excel Percentile Function

Figure 7. Scenario 2: Step 7 Calculations

Table 32. Scenario 2: Steps 7–8 Calculations

Percentiles		Losses	
Confidence Level	**Operational VaR (Percentile of Loss Distribution)**	**Overall EL (Aggregate Loss Distribution)**	**Overall UL (Operational VaR - EL)**
95.00%	$ 210,169.50	$ 117,735.00	$ 92,434.50
99.00%	$ 218,385.90	$ 117,735.00	$ 100,650.90
99.90%	$ 220,234.59	$ 117,735.00	$ 102,499.59

8. Calculate the overall UL. Subtract the overall EL from the operational VaR. See Table 31 for calculations. Figure 9 is a depiction of the loss distribution at the 95th percentile that shows how the overall EL and UL equate to the operational VaR.

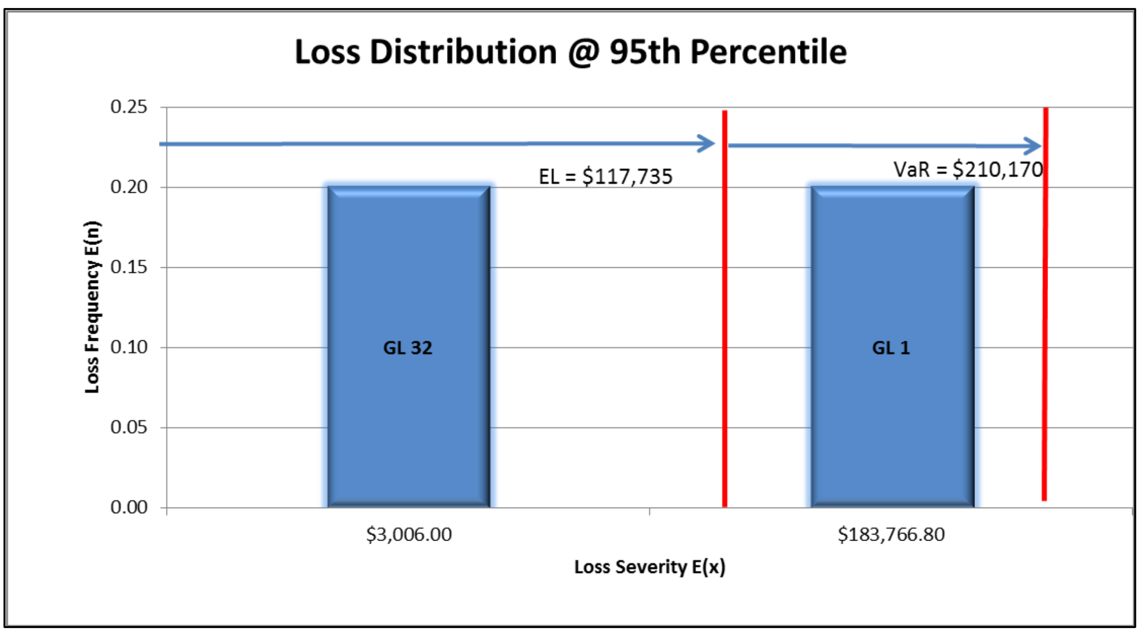

Figure 8. Scenario 2: Loss Distribution Chart at 95th Percentile

9. The withhold amount caused by the deficiencies is the calculated operational VaR not to exceed the maximum 5% of contractor progress payments.

Table 33. Scenario 2: Total VaR and Withhold Amount Determination

VaR at 95% Confidence Level	$ 210,169.50
Monthly Progress Payments	$ 4,829,268.29
Monthly Maximum Withhold Amount	$ 241,463.41
Final Amount to Withhold	$ 210,169.50

Scenario 2 shows that the total operational VaR for EVMS guideline deficiencies (1 and 32) is approximately $210,170. In this case, the risk caused by the EVMS deficiencies did not exceed the maximum withhold amount of $241,463. The severity of the two EVMS deficiencies for Contract YY equaled to a progress payment withhold of approximately 4.4%.

D. SUMMARY

In this chapter, we have analyzed the severity for each of the 13 high risk EVMS guidelines and developed a rank order of severity. By obtaining a rank order of severity, we were able to assign each guideline with a weighted risk factor which ACOs can use in prioritizing their limited resources on their surveillance of high risk guidelines. In scenario 1, the operational VaR exceeded the federal maximum withhold amount. In scenario 2, the operational VaR was below the maximum withhold amount. Both scenarios demonstrate that ACOs can benefit by objectively justifying withhold amounts.

The next chapter, *Conclusion*, answers each research objective, provides recommendations for the DCMA, and discusses our research limitations.

VI. SUMMARY, CONCLUSION AND FURTHER RESEARCH

A. SUMMARY

In Chapter I, we discussed the purpose of our research by explaining the Pentagon's new business systems rule and our intent to focus solely on EVMS. The new business system rule addresses deficient contractor business systems and the DCMA's authority to withhold 5% of contractor progress payments when a significant deficiency is present. Contractors are held more accountable and punished monetarily for failures to comply with EVMS guidelines under the new business rule. Our research efforts benefit the DCMA by recommending a quantitative risk analysis tool that can be used by ACOs to justify the amount of payment withholds.

In Chapter II, we provided an in-depth overview of the 13 high risk EVMS guidelines that DCMA EVM specialists asked us to focus on. This chapter laid the foundation to understand root causes and severity of EVMS significant deficiencies. We used case examples from the F-22 Spiral 2 program, GAO report on cost estimation and assessment, and EVMS subject matter experts in providing common examples of deficiencies for each of the guidelines.

In Chapter III, we described quantitative risk analysis in DoD acquisitions. This chapter provided key concepts in answering our research objectives. ACOs can calculate the risk to the government by applying the operational VaR model to justify the amount to withhold from contractor progress payments. The operational VaR model is recommended because it takes into account the frequency of the loss event occurring and the severity of loss in calculating risk. We also explored the pairwise comparison methodology to assist us in developing a rank order of the 13 high risk EVMS guidelines.

In Chapter IV, we discussed the eCAR database and obtained the loss frequency of the high risk guidelines, which is required for the application of the operational VaR model. Establishing the rank order of severity for the EVM guidelines was conducted in three stages: Rank ordering of the EVM group, using the pairwise comparison score to rank order the corresponding guidelines within each group, and then combining both

EVM group and guideline rankings to obtain the overall ranking from 1 to 13. The risk factors for each rank item were established using the rank sum methodology, which provide ACOs a means to prioritize their surveillance activities.

In the last chapter, we analyzed the risk severity that each guideline posed and developed a rank order of severity for each of the 13 guidelines. Upon obtaining a rank order for each guideline, we applied the operational VaR method to two different EVMS guideline significant deficiency scenarios.

B. CONCLUSION

The intent of this project was to objectively and quantitatively portray EVMS risk in a way that supports a monetary withhold decision and can withstand objection (to include litigation) from the defense contractor. In this project, we hypothesize that using quantitative risk models such as the operational VaR method and simplification of that business model for use by contracting officers provides value to DCMA professionals in the implementation of the new business rule. Our project focused on providing the DCMA with a more defensible risk value model as the basis for withholding contractor payments. In order to assist our research efforts, there were three project objectives. The following are the findings and recommendations associated with each research objective:

1. Determine whether the 13 EVMS "high risk" guidelines can be grouped with respect to root causes (causality of risk).

a. Findings

This research objective required us to evaluate the rank or natural order to the potential severity of the deficiency posed by these guidelines and to assess the degree of inter-dependence or causality across the 13 critical EVMS guidelines. We found that the high risk guidelines were already assembled within an EVM group for which the group's function served as associated root causes of risk as shown in Table 7.

By first ranking the severity of the EVM group, each guideline fell into a category of risk for a program. By conducting a pairwise comparison, we were then able to rank order each guideline within its respective EVM group to determine the overall rank order of severity as shown in Table 17.

b. Recommendations

Using our rank order methodology, the DCMA could conduct a more formal method of rank ordering high risk guidelines based on ACO and EVM subject matter experts within this field. An accurate rank order of GL severity is essential to prioritizing the DCMA's limited resources to fixing and monitoring the most severe GLs.

2. Evaluate which quantitative method(s) can be used to calculate risk value with respect to non-compliance with both critical and non-critical guidelines.

a. Findings

In this research objective, we found the operational VaR model to be applicable in calculating risk value of non-compliant guidelines and identifying quantitative definition of significant deficiency. In Chapter V, there are two scenarios in which we calculate the monetary risk to the government in nine steps. By obtaining a loss frequency and a loss severity for each significant deficiency, we were able to calculate the total operational VaR for EVMS deficiencies. We found that the monetary amount to withhold differs based on the EVMS significant deficiencies or guidelines.

b. Recommendations

The nine steps recommended for calculating the operational VaR are a valuable quantitative risk analysis tool that the DCMA could implement in determining or justifying withhold amounts for EVMS deficiencies. The quantitative model is objective and removes any type of subjective discretions that an ACO may consider in the amount to withhold from the contractor. In the event EVMS deficiencies calculate to more than 5% of progress payments, ACOs will have the confidence to withhold the maximum allowed. Conversely, if EVMS deficiencies only equate to 3% of withholds, the contractor will feel confident knowing that the withhold amount was not based on the discretion of the ACO but rather an established quantitative risk analysis tool.

3. Determine the relationship of risk value calculations and findings of EVMS non-compliance with: (a) probability of error, (b) magnitude of errors, and (c) adverse impact of errors

a. Findings

By gathering data from the eCAR database, we were able to obtain the probability of error, also known as loss frequency, used in calculating the expected loss. By using the contractor and government's administrative costs of pursuing and processing a CAR to include cost overruns as a result of the deficiencies, we were able to obtain the magnitude of error (loss severity). The mean of the loss severity was multiplied by the mean of the loss frequency to obtain the overall expected loss, which allowed us to obtain the operational VaR to the government, also known as the adverse impact of errors.

We found that by using the operational VaR formula, we are able to calculate EVMS non-compliant risks by obtaining the probability, magnitude, and adverse impact of error to obtain a monetary risk value. This research objective required us to develop a deterministic rule set that yields a consistent and repeatable finding of significant deficiency. Thus, we found the nine steps to calculate the operational VaR as the rule set that objectively and consistently yields the risk value of EVMS significant deficiencies.

b. Recommendations

By using the nine steps as listed in calculating the operational VaR for EVMS deficiencies, ACOs can be confident in withholding calculated monetary amounts. Contractors will understand the importance of correcting severe deficiencies. Severe deficiencies hold a higher monetary risk amount to the government and vice versa. Furthermore, this deterministic rule set can also be used as a guide for corrective action enforcement by putting a calculated withhold value on each CAR level I or II to warn contractors of the potential payment withholds that might come with a CAR level III or IV.

C. RESEARCH SHORTCOMINGS

Every effort has been made to gather information for an accurate and thorough severity analysis of each guideline. Our initial methodology included conducting a pairwise comparison of the high risk guidelines through a survey distributed to Divisional Administrative Contracting Officers (DACO), ACOs, and EVM subject matter experts. Due to the DCMA's legal constraints, the survey was not approved in a timely manner. Professional input from DACOs, ACOs, and DCMA EVM subject matter experts would have assisted in rank ordering the EVM groups and guidelines.

We recommend that in the future the DCMA conduct a formal rank order analysis of their high risk guidelines based on the experience and working knowledge of their personnel in order to develop a more accurate risk factor for each guideline. The survey we developed is still available for use by DCMA as shown in the appendix.

Secondly, because we intended to distribute a survey, we decided to keep the number of questions limited in order to encourage responses. Thus, we only conducted a pairwise comparison among guidelines within the same group to limit the questions to 21. However, a more accurate pairwise comparison should have compared all guidelines to one another, which would have resulted in 78 comparisons or questions. Furthermore, our pairwise methodology limited our rank order analysis to ranking guidelines only by the rank of their respective EVM group.

Third, we recommend that the eCAR database include both the government and contractor's administrative and labor costs associated with pursuing and processing a CAR to completion to include any cost overruns that the deficiencies cited in the CAR created for the government. These costs are considered the loss severity to the government and essential in calculating an accurate VaR to the government.

Last, due to competition-sensitive information, we were unable to interview the ACO for the DCMA at Lockheed Martin (LM) in Sunnyvale, CA. This DCMA branch was one of two branches; the other was LM in Fort Worth, Texas, that has withheld contractor progress payments since the implementation of the new business rule. Insight into the actual circumstances of what caused the ACO to withhold payments and at what percentage could have highly contributed to our research efforts.

Despite our research shortcomings, the information gathered and analyzed lays out the foundation to developing a more accurate rank order analysis that can be used to realistically calculate the operational VaR and withhold amount. At the conclusion of this project, we still met our research objectives and validated that the operational VaR model can be used as a defensible risk value model as the basis for withholding contractor payments.

D. AREAS FOR FURTHER RESEARCH

During the course of the project, we identified several areas for further research regarding EVMS deficiencies and the VaR model. For interested researchers, we recommend the following for future areas of research:

- We recommend evaluating the root causes of deficiencies for the remaining 19 guidelines (2, 4, 5, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 29, 20, and 31) that were not included in this research. We also recommend ranking all 32 guidelines for severity by experienced EVM specialists.

- We recommend obtaining contract data for both LM Sunnyvale and LM Fort Worth and apply the VaR model to determine if there were any differences in a quantitative verses a subjective withhold amount determination. Once this is completed, the operational VaR model should be verified, validated, and accredited (VV&A) by an independent agency, The Director, Cost Assessment and Program Evaluation (CAPE) might be the correct level of VV&A.

- Future research should include a sensitivity analysis of the risk factor determination, pairwise comparison, and VaR model to recommend modifications or additions to the model. Sensitivity analysis would examine the sensitivity of inputs to the VaR model based on changes to the guidelines that are deficient.

- Other areas for research include searching for best practices from private industries in evaluating risk. Can risk management models from other private industries be applied to the business system deficiencies? The variance-covariance method, Monte Carlo simulation, risk metrics, and other quantitative approaches can be researched to find the most efficient VaR model.

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APPENDIX. 13 EVMS HIGH RISK GUIDELINE (GL) SURVEY

The purpose of this survey is to evaluate the rank or natural order to the potential severity of the deficiency posed by the selected 13 EVM high risk guidelines (1,3,6,7,8,9,10,12,23,26,27,28,32). This research project excludes the accounting EVM category and guidelines and focuses on only 13 guidelines that Senior DCMA Earned Value Management specialists have identified as high-risk guidelines. We are also assessing the degree of inter-dependence or causality across these critical EVMS guidelines. The data we collect from the survey will assist in our research efforts of objectively and quantitatively portraying EVMS risk in a way that supports a monetary withhold decision from the defense contractor.

You are invited to participate in a research study titled Deficient Contractor Business Systems: Applying the Value at Risk (VaR) Model to Earned Value Management Systems. We would like you to participate in an online survey. This survey will consist of 21 questions. During the survey you will be asked to provide information about your experiences, subject matter expertise, and professional opinion in regards to the EVMS process. Participation in this survey is only voluntary and any questions you do not answer will be respected.

There are 21 questions in this survey and will take no longer than 20 minutes to complete.

Rank Order of the EVM Categories

Based on your experience, rank order the selected EVM Categories (Organization, Planning, Scheduling, and Budgeting, Analysis, or Revisions) from most severe to least severe in deficiency.

Each category should be evaluated in terms of the severity, which is the consequence of the future occurrence of a significant deficiency. DFARS Clause 252.234–7002 (a) defines a significant deficiency as a: shortcoming in the system that materially affects the ability of officials of the Department of Defense to rely upon information produced by the system that is needed for management purposes.

EVM Categories

Organization (GL 1 and 3) defines the range of requirements prior to the project commencing.

Planning, Scheduling, and Budgeting (GL 6, 7, 8, 9, 10, and 12) requires a management control system that links the formal planning, scheduling, and budgeting of a project into a performance measurement baseline (PMB). This group of criterions establishes a project baseline that allows for a formal means of project discipline and assessment.

Analysis (GL 23, 26, and 27) requires routine submission of EVM data such as cost and schedule variances to maintain effective project management. Variances should be evaluated and mitigated with a corrective action to minimize the negative impacts on the project.

Revisions (GL 28 and 32) require approved changes to the project in a timely manner to allow for integration.

Click on an item in the list on the left, starting with your highest ranking item, moving through to your lowest ranking item.

Your choices

- **Group 1: Organization**
- **Group 2: Planning, Scheduling, and Budgeting**
- **Group 4: Analysis**
- **Group 5: Revisions**

Pairwise Comparison of the 13 High Risk EVM Guidelines

For each of the 20 questions below, select the guideline (1, 3, 6, 7, 8, 9, 10, 12, 23, 26, 27, 28, or 32) that poses a higher risk defined as a measure of future uncertainties in achieving program performance goals within defined cost and schedule constraints.

Each guideline (significant deficiency) should be evaluated in terms of the severity, which is the consequence of the future occurrence of that significant deficiency. DFARS Clause 252.234–7002 (a) defines a significant deficiency as a: shortcoming in the system that materially affects the ability of officials of the Department of Defense to rely upon information produced by the system that is needed for management purposes.

Select which guideline you think is a higher risk between the pair? Please also provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 1 Define Authorized Work (WBS Elements)
- GL 3 Integrate the System

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please also provide your professional input on why you chose the guideline to be a higher risk.

Choose one of the following answers

- GL 6 Schedule the Work
- GL 7 Identify Products, Milestones, and Indicators

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please also provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 6 Schedule the Work
- GL 8 Plan the Performance Measurement Baseline (PMB)

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please also provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 6 Schedule the Work
- GL 9 Establish Budgets for Work

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please also provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 6 Schedule the Work
- GL 10 Identify Work Packages

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please also provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 6 Schedule the Work
- GL 12 Identify and Control Level of Effort

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please also provide your professional input on why you chose the guideline to be a higher risk.

Choose one of the following answers

- GL 7 Identify Products, Milestones, and Indicators
- GL 8 Plan the Performance Measurement Baseline (PMB)

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 7 Identify Products, Milestones, and Indicators
- GL 9 Establish Budgets for Work

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 7 Identify Products, Milestones, and Indicators

- GL 10 Identify Work Packages

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 7 Identify Products, Milestones, and Indicators
- GL 12 Identify and Control Level of Effort

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 8 Plan the Performance Measurement Baseline (PMB)
- GL 9 Establish Budgets for Work

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 8 Plan the Performance Measurement Baseline (PMB)
- GL 10 Identify Work Packages

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Please provide your professional input on why you chose the guideline to be a higher risk.
Choose one of the following answers

- GL 8 Plan the Performance Measurement Baseline (PMB)
- GL 12 Identify and Control Level of Effort

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Will you also provide your professional input on why you chose the guideline to be a higher risk?
Choose one of the following answers

- GL 9 Establish Budgets for Work
- GL 10 Identify Work Packages

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Will you also provide your professional input on why you chose the guideline to be a higher risk?
Choose one of the following answers

- GL 9 Establish Budgets for Work
- GL 12 Identify and Control Level of Effort

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Will you also provide your professional input on why you chose the guideline to be a higher risk?
Choose one of the following answers

- GL 10 Identify Work Packages
- GL 12 Identify and Control Level of Effort

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Will you also provide your professional input on why you chose the guideline to be a higher risk?
Choose one of the following answers

- GL 23 Analyze Schedule and Cost Variances
- GL 26 Implement Managerial Actions

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Will you also provide your professional input on why you chose the guideline to be a higher risk?
Choose one of the following answers

- GL 23 Analyze Schedule and Cost Variances
- GL 27 Develop Revised Estimates of Cost at Completion

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Will you also provide your professional input on why you chose the guideline to be a higher risk?
Choose one of the following answers

- GL 26 Implement Managerial Actions
- GL 27 Develop Revised Estimates of Cost at Completion

Please enter your comment here:

Choose only 1 guideline from the following pair

Select which guideline you think is a higher risk between the pair? Will you also provide your professional input on why you chose the guideline to be a higher risk?

Choose one of the following answers

- 28 Incorporate Changes into Plans, Budgets, and Schedules
- 32 Document Changes to the PMB

Please enter your comment here:

Choose only 1 guideline from the following pair

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